HIGHLY IONIZED GAS ASSOCIATED WITH THE SMALL MAGELLANIC CLOUD

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ABSTRACT

High dispersion IUE spectra of SMC stars are examined to search for evidence of a widespread distribution of highly ionized gas. For all of the stars, absorption by C IV and/or Si IV is found near 160 km s^{-1}, and is attributed to nebular material. In addition, the stars show absorption by the high ion lines in the range 100-130 km s^{-1}. This absorption might indicate the presence of global distributions of these ions, such as a hot phase of the interstellar medium or a halo-like region.

INTRODUCTION

Evidence of widespread C IV and Si IV absorption at large z-distances, in the Galactic halo, was first demonstrated through IUE observations of stars in the Large and Small Magellanic Clouds (LMC and SMC; Savage and de Boer 1979, 1981) and has been confirmed with observations of high latitude Galactic OB stars (Pettini and West 1982). An important issue is whether other galaxies also possess extensive haloes. Such haloes have been suggested as the sources of QSO absorption line systems (Bahcall and Spitzer 1969). de Boer and Savage (1980) found that the ultraviolet absorption line velocity characteristics of SMC neutral and highly ionized gas are similar to those found for the Milky Way. This suggested that some, if not most, of the absorption in the highly ionized gas is occurring in a gaseous halo similar to that surrounding the Milky Way. However, Prevot et al. (1980) argued that the C IV and Si IV lines more likely arise in the nebular environments of the target stars. A recent discussion of this controversial subject is found in de Boer (1984).

In this paper we examine the high dispersion IUE spectra of a number of SMC stars to determine if evidence exists for a global distribution of highly ionized gas (as opposed to "local" or circumstellar distributions). Seven SMC stars are considered here. These stars (and their spectral types) are: HD5980 (OB?+WN3), Sk80 (O7 Iaf+), Sk108 (O6.5+WN3), Sk188 (WO4+O7 III), Sk82 (B0 Ia), Sk159 (B0.5 Ia), and HD5045 (B1-2 I). Interstellar line profiles for most of these stars can be found in Savage and de Boer (1979, 1981), Fitzpatrick and Savage (1983; Paper I), and Fitzpatrick (1984a, 1984b; Papers II and III, respectively). The reduction procedures applied to the data are discussed in Paper I.

DISCUSSION

The C IV $\lambda\lambda$1548, 1550 and Si IV $\lambda\lambda$1393, 1402 interstellar lines for the

stars considered here are shown in Figure 1. For several of the stars, one or more of the lines are affected by a cosmic ray hit in the spectrum or are located in extremely low signal/noise ratio regions and are not shown. Spectra of SMC stars typically show C IV and Si IV absorption in three velocity ranges: near 0 km s^{-1}, near 100-130 km s^{-1}, and near 160 km s^{-1}. The 0 km s^{-1} absorption arises in the Milky Way halo and is not considered here. The 160 km s^{-1} and 100-130 km s^{-1} components are discussed separately below.

a) 160 km s^{-1} Absorption

The strongest C IV and/or Si IV absorption at SMC velocities is seen toward the O and WR+O stars (HD5980, Sk80, Sk108, and Sk188) near 160 km s^{-1}. Among the other three stars in Figure 1, Sk82 and Sk159 show prominant Si IV near 160 km s^{-1}, with weak or absent corresponding C IV. No Si IV or C IV is positively detected in the HD5045 spectrum near 160 km s^{-1}, although the noise level is high. Fitzpatrick and Savage (1984) show that a velocity of 160 km s^{-1} indicates that the lines most likely form in the nebular environments of the stars (which are all similar kinematically). Stellar UV-photoionization is suggested as the dominant production mechanism, although other mechanisms are probably also at work. In particular, the presence of N V absorption at nebular velocities toward the well-observed star HD5980 requires an additional source of ionization.

b) 100-130 km s^{-1} Absorption

The 100-130 km s^{-1} component is most apparent in the C IV lines of Sk159 and HD5045. Its presence is revealed in the spectra of the O and WR+O stars by the asymmetric extension of the strong nebular lines to lower velocities. No 100-130 km s^{-1} component is seen in the Sk82 spectrum, but the most likely indicator of such a component, C IV λ1548, is unfortunately buried in the stellar P Cygni trough. For Sk159 and HD5045, the C IV lines indicate $N(C\ IV) = 3\text{-}4 \times 10^{13}$ cm^{-2} and the weakness or absence of Si IV gives $N(C\ IV)/N(Si\ IV) \geq 10$. Due to the severe blending with the nebular lines, no such measurements can be made for HD5980, Sk80, Sk108, or Sk188. N V absorption in the 100-130 km s^{-1} velocity range, blended with a higher velocity component, is seen in the HD5980 spectrum.

The O and WR+O stars are not suitable targets for an attempt to discriminate between a global and a local/nebular origin for the 100-130 km s^{-1} absorption. The velocity of the feature is 30-60 km s^{-1} more negative than expected for "normal" nebular material; however, high velocity motions are known to exist in the environments of early type stars (e.g., the Carina nebula; Walborn, Heckathorn, and Hesser 1984). Thus any suggestion of a global origin for these lines would be vitiated by the strong possibility of circumstellar or nebular contributions.

The presence of the absorption in the spectra of the B-type supergiants, Sk159 and HD5045, allows the serious consideration of a global distribution of the highly ionized gas. The stars are located in apparently quiescent environments and, while circumstellar/nebular origins cannot be ruled out, a

global origin seems at least as likely. Two types of global distributions suggest themselves - either a truly interstellar distribution (similar to the hot phase of the Milky Way interstellar medium) or a "circum-SMC" distribution (perhaps analogous to the Milky Way halo). Toward the stars considered here, the bulk of the absorption from the neutral interstellar medium occurs in the velocity range 130-140 km s^{-1}. A hot phase would not be expected to mimic exactly the velocity of the neutral material and the 100-130 km s^{-1} velocity is not inconsistent with such an origin. Alternatively, the high ionization absorption might be associated with diffuse low ionization stage absorption seen at about 100 km s^{-1} toward all of the SMC stars observed. It is shown in Paper III that the gas producing this absorption probably lies "above" (i.e., nearer to the Galaxy than) the main neutral interstellar complex. Such a situation is suggestive of the Milky Way halo. Also, the large N(C IV)/N(Si IV) ratio in the Galactic halo ($\sim$ 4-6) is similar to the value in the 100-130 km s^{-1} absorption. A discussion of a possible SMC "halo" is complicated by the fact that both the dynamics and the morphology of the SMC have likely been shaped by gravitational interaction with the Milky Way and the LMC (e.g., Fujimoto and Murai 1984). Thus, a circum-SMC distribution of high and low ionization stage gas might resemble the Milky Way halo in some respects, but the origin of such a distribution might be quite different (Songaila 1981).

In conclusion, examination of the available high dispersion IUE spectra of SMC stars suggests, or at least permits, the existence of a widespread distribution of highly ionized gas. This gas may exist in an SMC halo with properties similar to the Milky Way halo. However, other explanations for the origin of this gas are certainly allowed by the data.

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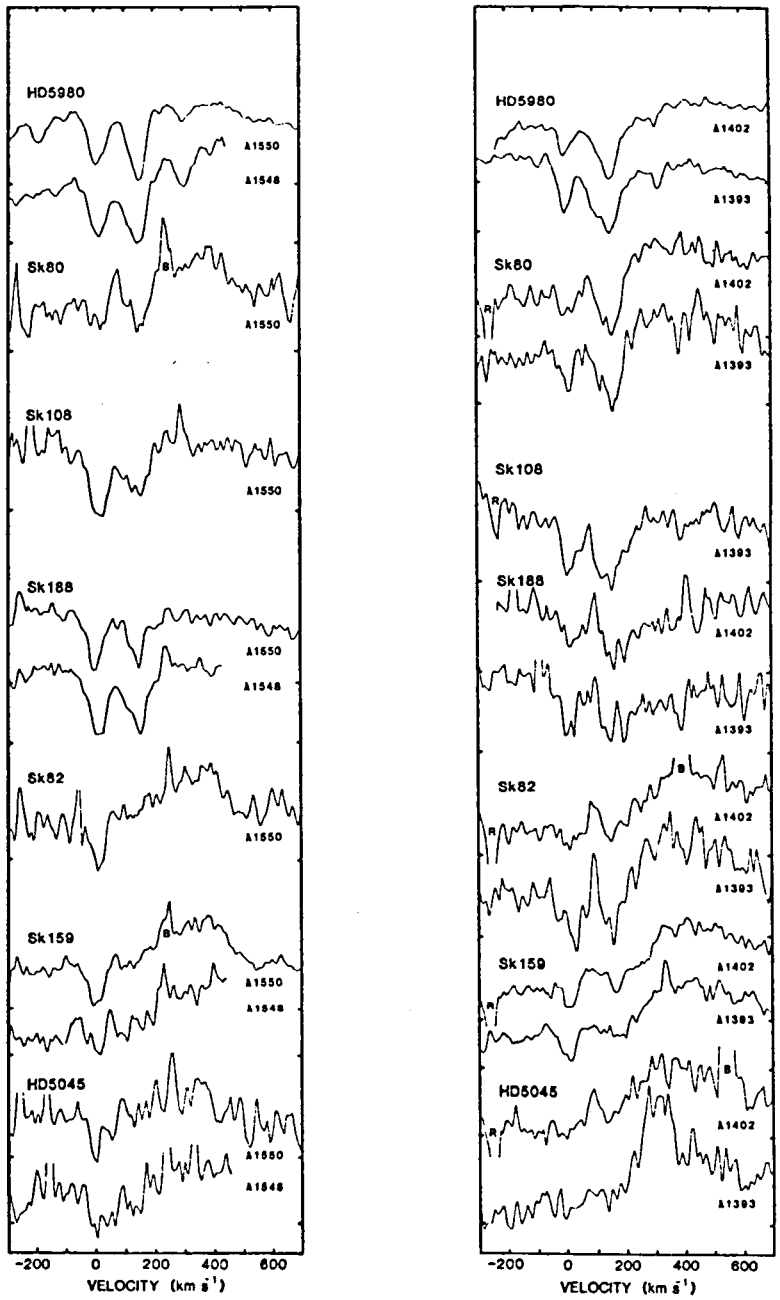

Figure 1 C IV λλ1548, 1550 and Si IV λλ1393, 1402 interstellar line profiles for SMC stars. Spectra are plotted on a net intensity vs. heliocentric velocity scale. Tick marks on the vertical axes indicate the zero levels. "B" denotes either a "hot pixel" or data affected by cosmic ray hits on the detector; "R" indicates a detector reseau mark. The highest quality data are for HD5980 and Sk159, for which 7 and 3 IUE spectra, respectively, have been combined.